Background Material for Yellow River Basin

Prepared by Yellow River Conservancy Commission

1. Basic information of the basin

1.1 Basin natural features

1.1.1 Geography

The Yellow River, originating from the Yueguzonglie basin on the northern part of the Bayankela Mountain in Tibet highlands at el. 4,500 m, is flowing through Qinghai, Sichun, Gansu, Ningxia, Inner-Mongolia, Shanxi, Shaanxi, Henan and Shandong nine provinces and autonomous regions, with a total length of 5,464 km, waterdrops 4,480 m, basin area 795,000 km^2 and, finally empties itself into the Bohai sea. (Including isolated inflow area 42,000km^2). It is the second largest river in China. (See 1.1.1 Sketch Map of the Yellow River Basin).

1.1.1 Sketch Map of the Yellow River Basin

The Yellow River basin has three stages from west to east in terrain and drops stage by stage. The top stage is the Qinghai Highlands on the northern part of the Qinghai highlands at elevation of 4,000 m or more, where distributes a number of north-west to south-east mountains and the Yellow River is flowing back and forth cross and through gullies and mountains in big “S” bend. The second stage is up to the Taihang Mountain as its eastern boundary, partially belongs to Inner-Mongolia Highlands and mostly belongs to the Loess Plateau at elevation of 1,000-2,000 m in differentials. The Loess Plateau starts from the Great Wall in the north, bordering Qinling

mountain in the south, western up to Riyue mountain and eastern to Taihang mountain with area of 630,000 km and loess layer from several 10 m to 200 or 300 m in thickness, where soil losses and erodes heavily due to soil structure soft, less grass coverage rate and gullies criss-cross. From the east of Taihang mountain to the sea beach, is the third stage, where mostly is the alluvial plain area of the Lower Yellow River 100 m below the sea level, the rolling area of Shandong province at elevation of 400-1,000 m and the delta area of the Yellow River mouth at elevation 10 m in terrain.

The main stream of the Yellow River is divided into three river reaches, the upper, middle and lower, according to its basin characteristics. (See Table 1.1.1 Characteristics Value of Each Reach of the Main Stream) The Upper Yellow River is rich in water resources where is the major water-originating place. The Middle Yellow River, flowing through the Loess Plateau with high intensity of heavy rain, where soil losses and erodes severely and, floodwater and sediment both are two most crucial problems in flood-control and sediment disposal over the Lower Yellow River. The Lower Yellow River is the “suspended ” river and flood-control is really challenging task.

Table 1.1.1 Characteristics Value of Each Reach of the Main stream

Reach	Place in between	Basin area (km^2)	Reach length (km)	Slope (‰)	percentage	Tributary (number)
Whole R.		794,712	54,63.6	4,480.0	8.2	76
Upper R.	Sources-Hekouzhen	428,235	34,71.6	3,496.0	10.1	43
Middle R.	Hekouzh-Taohuayu	343,751	1,206.4	890.0	7.4	30
Lower R.	Taohuayu-Estuary	22,726	785.6	93.6	1.2	3

1.1.2 Climate

The Yellow River basin locates in between of the dry area of north-west China and wet area of south-east China, where mostly belongs to the arid and semi-area of continental monsoon climate and be controlled by the cold air ball from the polar torrid zone with more north-west winds and in scarcity of precipitation and snow. In summer, the high pressure of sub-tropical zone with rich water air and more precipitation mainly affects it. The annual averaged temperature within the Yellow River basin is between – 4 - 14 C with averaged precipitation 478 mm for years and total precipitation volume 370 billion m^3. The annual precipitation distribution trends to be more in south, less in north, more in east and less in west and, reduces from 600 mm downward to

200 mm more or less progressively from south-east to north-west in great differentials.

1.1.3 Water and Sediment

The Yellow River is well-known sediment laden river throughout the world. The annual averaged delivery of sediment through Sanmenxia calculates approximately 1.6 billion t with averaged sediment content 35 kg /m^3, however, the total volume of annual runoff is merely 58 billion m^3 within the whole basin. The sediment of the Yellow River mainly originates from the Loess Plateau of the Middle Yellow River, mostly concentrates over the areas between Hekouzheng to Longmen and that between Longmen-Tongguan, which constitutes 90% of the total volume of the Yellow River sediment and the silt in grain size more than 0.05 mm in diameter is also mainly from these two areas.

The water and sediment of the Yellow River is mainly characterized by (1) less water and more sediment and, high sediment content. The water volume of the Yellow River is no more than one-twentieth of that of the Yangtze River, but the sediment is three times more than that of the Yangtze River, which is very seldom seen among the rivers throughout the world. (2) Unevenly Distribution of different sources of water and sediment. The water of the Yellow River mainly yields from the Upper Yellow River and the sediment mainly from the Middle Yellow River and, the upper river water mostly comes from the reach above Guide. The sediment yield on the Middle River is also extremely concentrated, the regions where sediment transport modulus more than 10,000 t/km.a are only the three segment areas, the tributaries between Hekouzheng to Shuiguan of Yanan, the river sources in Baiyushan and the river sources in Liupanshan mountain; (3) Great changes between water and sediment and unevenly distribution in a year. For example of 11 years of continuously dry from 1922-1932, the observed maximum flow at Sanmenxia is 65.9 billion m^3 (1937), and the minimum is 20.2 billion m^3 (1928), which differs 3.2 times in that, however, the annual maximum delivery of sediment is 3.91 billion t (1933) and the minimum is 488 million t (1928), which differs 8 times in that; Moreover, the water and sediment annual distribution is unevenly as well, mostly concentrates in the flood season or even in a few floods events.

1.1.4 Natural hazards.

The drought frequently happens to within the Yellow River basin in the history, therefore, it has been called as the “Sorrow of China”. Most of the basin belongs to the arid and semi-arid area with less precipitation, greatly variation and frequent droughts. According to statistics, for a period of 3,711 years from BC 1766 to AB 1945, there are recorded 1,070 times or more of big droughts that have brought about great sufferings, just 201 times out of which occurred in Qing Dynasty, about one time out of one more year on average. From 1877 to 1879, there occurred continuous three years droughts, which killed about 13 million people in Shanxi, Hebei, Shandong and Henan four provinces; and the drought in 1929, about 34 million people of the provinces in the Yellow

River basin struggled for existence on the verge of death. Many historical documents and current data convince that the drought happens to within the Yellow River basin with great frequency, large area and more affected people. For 42 years from founding the People's Republic of China to 1990, there always occurred droughts in the farming area of the Yellow River basin, especially the cropped land without any yields reached to 70,000 hm^2 due to the drought in 1982 and grain output reduced by 3.32 million t due to the drought in 1980.

The flood on the Lower Yellow River has been the focus of the world attention in the history. For 2,540 years, from the fifth year of Zhouding King (BC 602) to 1938 as the manually opening the main dyke, there are recorded dyke-breaches 543 times years that causing flooding and dyke-breaches 1,590 times, five significant channel changes and shifts with inundated area North up to Tianjin, South to Yangtze and Huai River basins, including the Huanghuaihai Plain of Hebei, Shandong, Henan and Jiangsu five province with total affected area of 250,000 km^2 and great disasters.

1.2 Social and economic background

1.2.1.Population

People had started inhabitation in the Yellow River basin 1 million years ago and Stone Age cultural ruins widely scattered over the basin and a plenty of systematical cultural relics of the mankind in different periods are preserved there. The inscriptions on bones or tortoise shells recorded the human history are also excavated on the bank of the Yellow River. Therefore, the Yellow River basin is praised as the cradle of the Chinese nationality.

According to the statistics of 1990, a population of 97.81 million people is settled in the Yellow River basin, constituting 8.6% of the total nation number. Among the over all 56 nationalities in China, there are 9 nationalities in the Yellow River basin, among which, the Han nationality is the major one, occupying 92.5% of the total inhabitants in the basin, Huis 1.67% and the next others are the Mongolians, Dongxiangs, Tus, Slas, Baoans as well as the Mans.

1.2.2 Land and mineral resources

The Yellow River basin is rich in land and mineral resources with total land area 79.33 million hm^2, constituting 8.3% of the total country land area, among which, 11.93 million hm^2 is the cultivated land, 10.20 million hm^2 is forest and forage land 27.93 million hm^2. Additionally, about 2 million hm^2 of wasteland is available for reclaim.

In 1990, among the proven 45 major mineral deposits in China, 37 of those kinds are deposited in the Yellow River basin. The deposited volume more than 32 % of that in China are the rare-earth metal, gypsum and coal and so on 8 kinds. And that about 16%-32% are oil and mirabilite and 10-16% are natural gas, alkaline, copper and gold six kinds. The water energy on the Upper Yellow River, the coal on the Middle and the oil and natural gas on the Lower are all quite rich in deposits, therefore, the Yellow River basin is also called as the "Energy Basin"

playing a considerable position in China.

1.2.3 Industry and agriculture

The Yellow River Basin has been the agricultural economic development zone in our country since very early time. The Hetao Plain between Ningxia and Inner Mongolia Autonomous Regions on the upper reach is a successful model project of “Greenland Agriculture ”for the improvement and practices on the arid-area. And the basin between Fen River and Wei River on the middle reach is one of the major grains and cotton production bases of our country as well, like the wheat, cotton, oil and tobacco agricultural products which play an important role in China.

A number of newly built industrial bases and cities have been set up in the Yellow River basin. Energy industries including coal, power-generation, petroleum and natural gas have obviously superiority in resources. The raw coal production output occupies more than half of the total that of the country and petroleum production output roughly covers one fourth of the nationwide. Nonferrous metallurgical industries, like Lead, zinc, aluminum, copper, molybdenum, tungsten and gold as well as rare-earth industry also have comparative superiority. And the textile industry has an important position in our country as well.

1.2.4 Culture and human activities

The Yellow River Basin is the cradle of Chinese nationality. In the very long historical period, the Yellow River basin has been the center of politics, economy, and culture of China. As early as one million years ago, “The Lantian Man” had been living in the Yellow River Basin, and “Dali Man” “Dingcun Man” and “Hetao Man” etc. ancestors one generation after another had been living and working along the Yellow River, and created magnificent ancient civilization. The remains of ancient culture like Yangshao Culture, Majiayao Culture, Dawenkou Culture and Longshan Culture can be found everywhere in the whole river basin from upper reach to the lower reach.

About 4000 years ago, the tribe had been set up in the Yellow River Basin typically represented by Yan Emperor and Huang Emperor, and descendants of Yan and Huang Emperors mixed together with other tribes and established “Chinese Nation”. From the founding of the Xia dynasty in 21 century BC to now, more than 4000 years have passed. China’s capital has been settled in the Yellow River basin for 3000 year odd. Four out of the six most famous ancient capitals in China are in the Yellow River basin.

Natural landscapes of the Yellow River basin are grand and spectacular in viewing. Tourist resources are very rich. Mountain Riyue, Mountain Jishi, Mountain Helan, Mountain Liupan, Mountain Luliang, Mountain Zhongnan, Mountain Hua, Mountain Tai, and the Longyangxia Valley, Liujiaxia Valley, Yumenkou Valley, Sanmenxia Valley, etc. are precipitous and deep. The famous Hukou waterfall is located in the Valley between Shanxi and Shaanxi, Water gallops and roars through the valley with a heroic spirit that conquers mountains and rivers.

1.3 History of river evolution

The formation of the Yellow River has passed through long geological era. As early as one million years ago, it was Pleistocene, many lakes spread within the Yellow River Basin, they did not link with each other, and each lake had formed its independent water system. But later on, the movement of the Himalayas made a large area of earth rising and falling vertically, and western plateau quickly rose and North China plain gradually subsided. The drop of topography from west to east became bigger. In addition, the lakes and basins had merged with each other gradually by the long term erosion and invasion, and finally, the large river had been formed as a whole from the upper to the lower part. By the synthetic analysis and deduction, it has 1.5 million years long history since the formation of the ancient Yellow River. The Yellow River got its name because of the yellow color of muddy water, and in the ancient books, it was called the River. The Yellow River was firstly called in the "Book of Han Dynasty".

1.3.1 River channel shifting and flood protection area

1.3.1.1 Shifting of the river channel

In the past historical period, normally, there were no great shifts occurring for the river channel of upper and middle reach. Only the river channel on the lower reach shifted frequently. Taking Zhengzhou city as axle center, it shifted to Tianjing in the North, and reached Yangtze River and Huaihe River in the south, crossing the plain among the Yellow River, Huaihe River and Haihe River with total area of 250,000 km^2. And tracks of the shifting can be found almost everywhere. There were eight times of major shifts occurring on the lower reach of the Yellow River during 2000 years odd since the Warring States to now. The first major shifting occurred in the fifth year of Zhouding Emperor (602 BC) by the historical record. Since then to the early year of Jin Dynasty, it was 1700 years odd, and the lower river channel only shifted in the northern part of the Yellow River and flowed into Bohai sea. Since second year of Jianyuan of South Song Dynasty (1128 AD), Duchong who was the officer in charge of Dongjing (Kaifeng city) breached dykes of the Yellow River in order to stop the troops of Jin State going to the south, which caused the Yellow River flow into Huanghai sea crossing Huaihe River. After that time, the shifting had occurred frequently in the south of current river channel for 700 years. In the fifth year of Qingjianfeng (1855 AD), the dyke breached at Tongwaxiang (Dongbatou, Lankao county, Henan province) which caused the Yellow River flow into Bohai sea after crossing the Daqinghe River. In 1938, the Guomindang Authority burst dyke at Huayuankou near Zhengzhou City in order to stop Japanese invasion to the west, which caused the Yellow River flow into Huaihe River. In 1947, after closing the dyke at Huayuankou, the Yellow River recovered its old course and remains its downstream channel till now.

At present, the river channel has been formed steadily between the dykes during the process of long-term flood release and sediment transportation. The riverbed is normally 3-5m higher than

backside ground on average, the maximum 10 m higher, and will be raised 0.05-0.1m high on average annually. The section above Gaochun is the meandering section with width of 5-20m between dykes. The section between Gaochun and Taochengfu is called transition section, 1.5-8.5m wide between both dykes; and section between Taochenfu and Lijing is called wandering section with 0.4-5m width between both dykes; the section below Lijing is called estuary section. And 1 billion ton sediment will be transported into estuary area on average annually, with extending of aggradation, the new land with area of 25-30km^2 will be created annually on average. In order to control the shifting of river mouth, and properly arrange channel to the sea, the river channel have been artificially shifted for three times since 1949. The current channel to the sea has been formed since artificial shifting of Qingshuigou in 1976.

1.3.1.2 Protection area of flood control

The protection range of flood control on the lower reach is taking Zhengzhou as axle center, and it reaches Haihe River in the north, and Yangtze River and Huaihe River in the south, the total area is 250,000km^2. Based on the information of historical floods, combining with analysis and deduction of variation of topography and ground matters, if the dyke burst once in the north or in the south and keeping the current river channel without occurrence of major shifting, the maximum impacted range in the north would be 33,000 km^2 and 40,000 km^2 in the south. The total area would be 120,000 km^2, and cultivated land 7.33 million hm^2, population 78.01 million within flooding affected area.

1.3.2❄ Flood features of the river

The Yellow River has four kinds of floods in a year called peach flood, summer flood, autumn flood and ice run flood. The summer flood is caused by heavy storms. The autumn flood is caused by an unbroken spell of wet weather during the period from September to October. The summer flood and autumn flood are the most dangerous, usually called “summer and autumn flood”. The ice run flood is caused by ice blocks in winter which make the water level rising suddenly and threatening the safety of the embankments in the sections of Ningxia, Inner Monggolia, Henan and Shandong. The peach flood is happened during March and April when peach trees are blossoming and ice and snow melt in the upper reaches, causing water level rises in the lower reaches.

The floodwater, being characterized by high flow peak, short duration and abruptly rise and fall, mainly comes from the Middle Yellow River. There are three floodwater original sources on the Middle Reach; the first one is between Hekouzheng-Longmen, the second one between Longmen-Sanmenxia and the last between Sanmenxia-huayuankou. Different floods from different areas will all form their own major and extraordinary floods in different formations at Huayuankou station. The occurrence of flood above Sanmenxia is called “Upper Main Flood”. For events of floods of 1843 and 1933, both are the typical “Upper Main Floods”, which are

characterized by high flow peak, huge flow and sediment that normally forming high sediment laden flow and the flood-control is significantly threaten. The flood in between of Sanmenxia to Huayuankou is called “Lower Main Flood”, the floods of 1761 and 1958 are the typical “Lower Main Flood” with characteristics of water level rise and fall abruptly, high flow peak, less sediment laden flow and short predict period that had mostly threaten the flood-control in all. The historical survey show us that the biggest flood occurred in 1843 with peak flow 36,000 m^3/s at Shanxian Observation, and the observed occurred in 1958 with peak flow 22,300 m^3/s at Huanyuankou Observation.

1.3.3 Organizations and institutions of the basin

It is said that it had administrators special for water management as early as in the dynasties of Xia, Shang and Zhou. At that time the management of the Yellow River had become an important matter of the state. Since Qin and Han Dynasty, governments at all levels along the river all had the responsibility of river management. In the Cheng Emperor reign of Han Dynasty, it had full-time officers for river management and established river management units at city and county levels that were located along the river since Song Dynasty. In Jin and Yuan Dynasty, the river engineering works in the lower reaches were protected together by the army and people. It had channel premier in Ming Dynasty and had channel governor in Qing Dynasty. In 1933, the government of the Republic of China established Yellow River Conservancy Commission (YRCC), being responsible for the management of the river, except the river engineering works of Shanxi, Henan and Shandong were still managed directly by each province because of big floods occurred in the Yellow River and heavy disasters in the lower reaches.

In 1946, YRCC established Hebei Repairing Division in the north suburbs of Zhengzhou, beginning to unify river managing organizations but which was not the institution for the whole river basin management. On Jan. 25th 1950, the State Council of the Central Government decided to make YRCC as a basin-wide organization, being responsible for the management and development of the whole basin and all the institutions for river harnessing in Shandong, Henan and Pingyuan (Shanxi) provinces were under the leadership of YRCC.

In 1989, YRCC has been upgraded from a department level to a vice-ministry level, which was approved by the State Council via the Ministry of Personnel. It is a basin-wide organization under the leadership of the Ministry of Water Resources (MWR), an agency of MWR for the management of the Yellow River basin and inland river areas of Xinjiang and Inner Monggolia Autonomous Region. It is authorized by the state to conduct the duty of water resources management in the above mentioned regions. It unifies the management of the water resources and channel of the basin according to the principle of unified management and management by each level. It is responsible for a comprehensive management of the basin, key and important engineering works, conducting planning, management, coordination, monitoring and service, promoting river management and water resources development, utilization and protection.

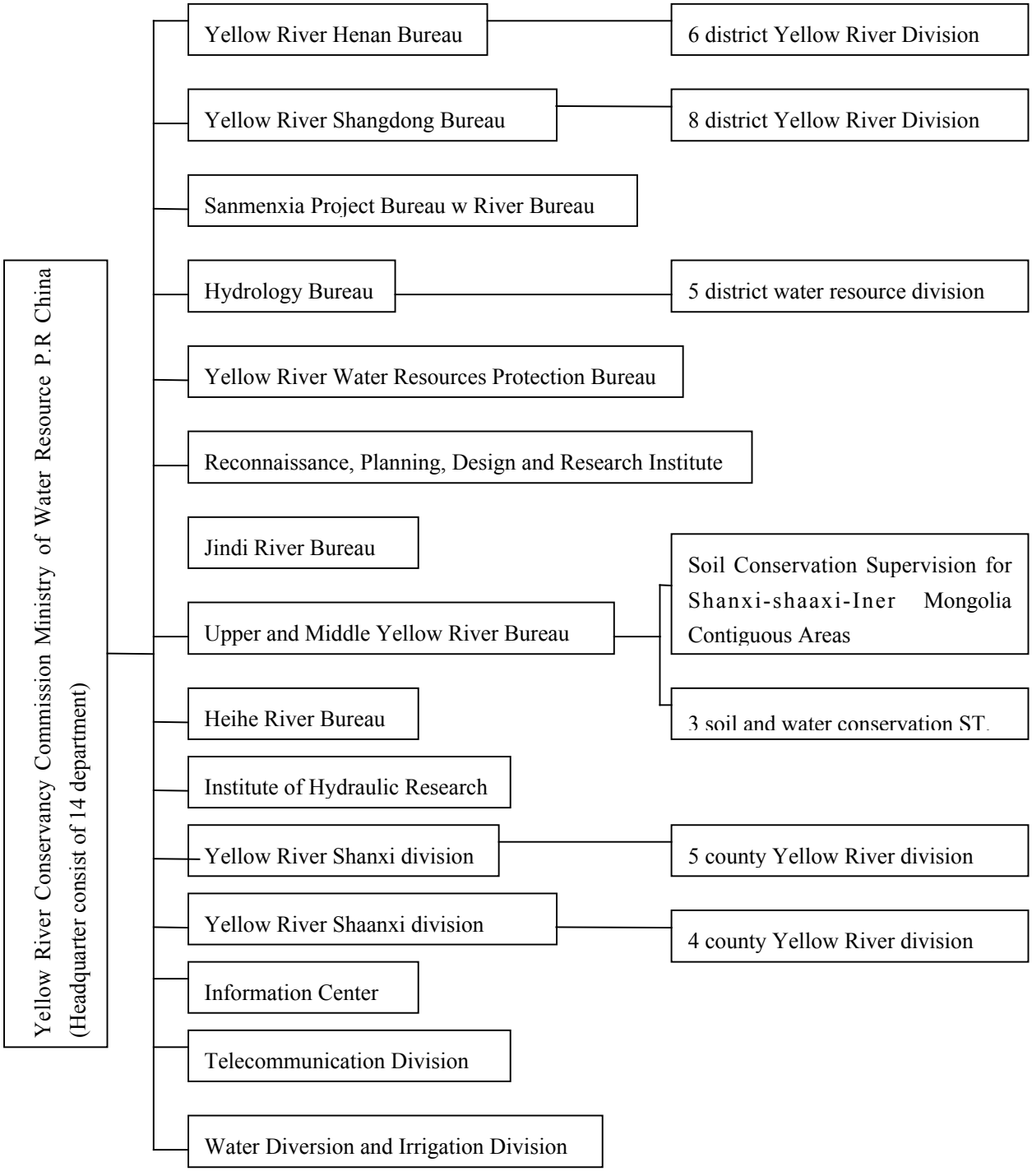

Fig 1.4 Organization chart of Yellow River Conservancy commission

The headquarter of YRCC is situated in Zhengzhou, Henan Province and its branch institutions are scattered in each province along the Yellow River. By 1996, the Yellow River

basin has formed a completed system on management and development of the Yellow River taking YRCC as a unified unit (see Fig. 1.4). The staff member has been increased from 3,041 in 1951 to 30,420 in 1996, increasing 10 times. The professional engineers are 9,347, making up 30.7% of the total number, among which, senior engineers 717, engineers 2,952 and technicians 5,678. YRCC has done a great deal of work on the aspects of flood control, survey, planning, development and utilization of water resources, hydrology, hydro-electric power, water and soil conservation, etc. achieving no dyke breaches during summer and autumn floods for 52 years running and making a great contribution to the social and economic development of China.

2. Management and achievements of the Yellow River

2.1 Construction of engineering works system on the lower reaches

2.1.1 Historical evolution of river harnessing

The Yellow River has a long history on river management due to frequent flood disasters happened in history. As early as in primitive society, it had popular legend of Yu The Great who controlled the river. In the period of Warring States, it had started to build dykes on the lower reaches. Jia Rang, a person lived in West Han Dynasty of 2000 years ago had put forward "Three Measures on River Management", which was the earliest document on river management policies in China. Wang Jing of East Han Dynasty led hundreds of thousands people to build about 500 km long canals and dykes through creatively adopting a measure of a gate in every 5 km. Pan Jixun, a famous expert on river management, adhered to the principle of "control water by building dykes and solve sediment problem by water" and conducted practice in a large scale, making the channel in the lower reach stable for a certain period. The lessons and experiences of those experts had made profound historic significant to the later generations.

The breach in the lower Yellow River was blocked in 1946. After returning back to the original course, YRCC had adopted the policy of "keeping wide river sections and strengthening embankments", built flood detention basins and conducted protection both by the army and people by using the historic experiences. Thus, it had greatly increased the capability of flood control and conquered the extraordinary flood in 1958. Along with the construction and development of soil conservation work in the upper and middle reaches and reservoirs built on the main and tributaries, a system of flood control engineering works of "retaining water at the upper stream, discharging at the downstream and retarding at detention basins on the both banks" has been formed. This had finished the passive situation of only relying on the dykes and conquered floods for years, including 6 severe ice run floods that were considered could not be managed by men in history and achieving a great success of no dyke breaches during summer and autumn floods for 52 years running.

2.1.2 Engineering works for flood-control

The short-term mission of flood-control is: to guarantee that the main dyke should not be breached under the flood peak of 22,000 m^3/s observed at Huayuankou Station and try all efforts to reduce hazard as much as it could in all cases under extraordinary flood.

Since 50's, a flood-control engineering system of "Holding water upstream, discharging downstream and detention by both banks" has been initially formed under the guidance of "Stabilizing the flow by widening river channel ".

2.1.2.1 Reservoirs regulation system

Key reservoirs as: (1) Sanmenxia Reservoir on the main stream with basin control area 688,000 km^2, constituting 91.4% of the total basin; (2) Lunhun Reservoir on the key Yihe trubutary with with basin control area 3,492 km^2, constituting 57.9% of the total basin of itself and total storage 1.32 billion m^3. This reservoir mostly serves as a supportive role for Sanmenxia reservoir in reduction of the flow peak from Sanmenxia to Huanyuankou and mitigating the burden of flood-control on the Lower Yellow River. (3)Guxia reservoir on the Luohe river with control area 5,370 km^2, 45% of its watershed, design total storage 1.175 billion m^3, mainly serving as supportive role for Sanmenxia, Xiaolangdi and Lunhun reservoirs in mitigating the threat of the flood on the Lower Yellow River and raising the flood-control standard for Luoyang city. (4)The Xiaolangdi Reservoir under construction,when it is completed, will control 694,000 km^2 area of the whole river basin, occupying 92% of the total, reservoir storage 12.65 billion m^3, 7.55 billion m^3 storage left for sediment deposition, long-term effective reservoir storage 5.1 billion m^3, is a multi-purpose hydro-structure with mian functions of flood-control, ice-run control and sediment mitigation and considerable functions like water supply, irrigation and power generation etc. It will effectively control the Yellow River floodwater and mitigate and slow the silt up of the river channel of the Lower Yellow River. (As shown in table 2.1.2)

Table 2.1.2 Main Design Indexes of the Regulation Structures for the Flood on the Lower Yellow River

Name	Type	Max. Height (m^3)	Normal level (m)	Design storage (million m^3)	Regulation storage (m^3)	Installed capacity (million kWh)
Sanmenxia	Gravity	106	335	9,640	5,700	0.4
Lunhun	Sandy-shell dam with inclined clay wall	55	319.5	1,320	576	0.001045
Guxian	Concrete gravity dam	125	534.8	1,175	708	0.06
Xiaolangdi	Earth-rock filled dam	173	275	12,650	4,050	1.8

2.1.2.2 Release works on the lower reach

*Protective dykes

Downstream dykes are main defense to fight against flood. Since people's harnessing the Yellow River, the downstream dykes have been rehabilitated for three times in a large scale, the first time was from 1950 to 1959, the second time from 1962 to 1965, and third time from 1974 to 1985. Through three times reinforcement and re-heighten of dykes, it greatly increases capability of flood control. Normally, the downstream dykes are 7m-10m high, the maximum height is about 14m, and 3m-5m higher than backside ground, the maximum up to 10m. The crest width of cross-section of dyke is 7m-15m. And slope of backside above Aishan is 1:3, and slope of riverside below Aishan is 1:2.5, slope of backside is 1:3. The total length of downstream dykes is 2,285.1km, out of which, the length of dykes near the river is 1368.3km, 312.8km dykes for retention area, 199,3km dykes for tributaries, and 247.3 km dykes for others, 157.2km dyke below Yuwa.

*Vulnerable spots and control works

The river training works on the lower reach of the Yellow River mainly includes two types: vulnerable spot and control works. Vulnerable spot attaches itself to main dykes in the form of dam, buttress and revetment to control river regime and to protect main dykes. Control works and floodplain protection works have been constructed in the front edge of floodplain in the form of dam, buttress and revetment and has function of controlling river regime and protecting floodplain and dykes. At present, 207 vulnerable spots and 6,259 dams, buttress and revetments have been constructed with total length of 394km. And 204 control works and flood plain protection works, and 3,793 dams and buttresses with the total length of 346km, 94 protection works for rolling river, 301 protection dams have been constructed on the lower reach of the Yellow River.

*Floodplain area on the lower reach of the Yellow River

The downstream river channel is from Tiexie of Mengjing county in Henan province to Kenli county in Shandong province and empties into the sea, the total length is 878km. The river channel is wide on the upper part and narrow on the lower part, and slope becomes flatter from up to down. The width between both banks on the wide section above Taochengpu, Shandong province ranges from 1.4 km to 20 km, from 0.5km to 5.0 km below Taochengpu. Normally, river channel is double channel, and plane external form appears type of joints of lotus root mixing wide section and narrow section together. For the wide section, there is wide floodplain in between. The floodplain has the good function of retention and alleviation of peak flood when the flood occurs. The total area of river channel is 4,647 km^2, out of which, floodplain occupies 3,956 km^2, taking 85% of the total.

2.1.2.3 Retention projects

*Dongpinghu Lake

Dongpinghu Reservoir is an important diversion works on the lower reach of the Yellow River. It is located within Shandong province with the total area of 627 km^2, the current total operation capacity for flood control is 3.05 billion m^3, out of which, new lake covers 2.16 billion

m^3, and old lake covers 890 million m^3. The main function of Dongpinghu is to solve issue of flood control on the narrow section below Aishan, and control release discharge not greater than 10,000 m^3/s below Aishan station, to guarantee the safety of Jinan city, railway between Tianjing and Shanghai, as well as large area along both banks below Aishan. Meanwhile, it has the function to regulate and store flood occurring on the Wenhe River. There are five intake gates such as Shiwa, Linxin, Shilibao, Xuzhuang, Gengshankou in Dongpingh Lake with diversion capacity 8,500 m^3/s, and there are three outlet gates such as Sike, Chenshankou and Qinghemen with total outlet capacity 3,500 m^3/s.

*Beijingdi Retention area

Beijingdi retention area is located on the left bank, 190km far away below Huayuankou, Zhengzhou city, where is near area between main dykes of the Yellow River and Beijingdi. And it was approved to be constructed in 1951 by State Council, and it is one of important structure measures to defense flood beyond standard on the lower reach of the Yellow River. The effective diversion of water in Retention area is 2 billion m^3, the total retention area is 2,316 km^2 which involves in 2,166 natural villages, 67 townships, 7 counties and Henan, and Shandong provinces, with population of 1.5723 million. The operation principle of Beijingdi Retention area is as follows: if the flood at Huayuankou station occurred above 22,000 m^3/s, and if the flood could not retained by Sanmenxia, Guxian and Luhun reservoirs combining with partially operation of Dongpinghu, it should be submitted to the State Council for approval of operation of Beijingdi Retention area to divert water. Quchun diversion gate, Zhangzhuang outlet gate and pre-left outlet on the dyke below outlet gate have been used for releasing water back to the Yellow River.

*Qihe River Widen works

Qihe River Widening Area is mainly to solve the issue of ice-run flood on the narrow section of Jinan, when the special flood occurs on the Yellow River, it can be used to retent part of flood. The total area of it is about 106 km^2 with effective retention capacity 390 million m^3. And Doufuwu diversion gate has been constructed near the main dyke and Dawu outlet gate has been constructed on the lower part of extension area to the Tuhaihe River.

*Kenli Widened Area

The Kenli Widened area locates in Kenli county, Shandong province, with main purpose of ice-run control, next to flood-control, sediment warping and irrigation in ensuring the safety of the inhabitants along the both banks and the development of the oil field production and agriculture. There are two inlets structures built in the main dyke at Mawan and Caodian and one outlet built on the lower part of the widened area at Zhangqiuwu. The widened works has an area of 123.33 km^2, with retention storage 327 million m^3.

* Dagong flood detention area

In 1956, the Dagong flood detention area was built up in order to fight against the extraordinary flood. The area locates in between the main dyke on the northern bank of the Yellow River south-east in Xinxiang city and the Beijindi Dyke with flood dentention area 2,040

km^2 covering areas of Fengqiu, Changyuan, Yanjing and Huaxian counties, Henan province. As operation, the floodwater will mostly flow through the Taihang canal into the Beijindei detention area and regress to the Yellow River through the outlet at Zhangzhuang, meanwhile, partial floodwater will regress to the Yellow River through the Taihang dyke and downward to Dacheji, Changyuan county. The Dagong detention area dose not equip with flood detention inlet structure, but with simple spillways cofferdam on the floodplain, one hundred meter away from and before the main dyke of the Yellow River at Dagong village, Fengqiu county, by bricking of galvanized wire rock cages and, one cut-off wall 1.5 m deep and 1.0 m wide made of galvanized wire rock cage was set up upstream and downstream and both tips were protected.

2.1.3 Non-engineering measures for flood control

The main non-engineering measures for flood control are flood control organization system, flood control communication system, hydrological observation and forecasting system, decision-making support system , regulation and commanding system, and, flood detention and retention basin management etc.

Flood control organization system: Under the leadership of the State General Headquarters for Flood Control, all the provinces along the Yellow River have established flood control headquarters and its administrative offices. The administrative chiefs of each level, governments should be the commmander who will be responsible for all affairs of flood control. The administrative offices for the Yellow River flood control are located in the Yellow River management units, responsible for the daily works of flood control.

The emergency squads for flood fighting are composed of the Yellow River specials team, mass team, the Liberation Army , and, the armed policemen.

Communication system for flood Control: The Yellow River special communication network is composed of advanced communication means like microwave, "a point to multi-sites" microwave, wireless system, satellite, mobile communication, short wave, ultrashort wave and PADX. Each means of communication is complemented and perfected each other. The all above means of communication have provided a reliable communication means for Flood Control. And also Warning Information Feedback System has been installed in the floodplain and retention area to guarantee the masses safely remove from there when the extraordinary flood occurs.

Hydrological forecasting system: There are 458 hydrometric stations, 58 water level stations, 2,376 rainfall stations all together in the Yellow River basin. At present, the way of observation is still done by hand. And, some self-recorder instrument have been only installed in a very few rainfall stations. The basic facilities of hydrometric stations are relatively completed. The method used for flood forecasting is still conventional way. The forecasting methods adopted in the Yellow River usually are decided through many years tests of flood forecasting and repeatedly revising based on practicality, physical cause of formation and a vast amount of observed data. Those methods are flexible to operate and easy to calculate which has formed a set of relatively

completed and applied forecasting method for storm flood and ice run flood of the Yellow River Basin. And the methods basically have met the requirements of flood control combining with the main stream and its tributaries.

The decision –making support system: The system was established based on the hydrological observation and forecasting data, rich historical data and the principle of regulation of flood control. And, the pre-scheme of flood regulation can be to quickly work out by using modern computer technology. And the data will be continuously revised in real time and will be provide reliable support for decision-making of flood control.

Management of retention basins: The task of detention basin administration is to well manage the retarding works, work out a plan for remove and relocation, conduct basic technical work of detention operation, and, protect retarding facilities.

Relying on engineering and non-engineering flood control measures mentioned above, and 12 times floods with the discharge above 1000m^3/s (including 1958 flood with discharge 223000m^3/s) have been conquered tha bring about a radical change in the history.

2.1.4 Examples of River flood

2.1.4.1 1958 flood

On July 17, 1958, a peak discharge of 22,300 m^3/s happened at Huayuankou Station where the maximum flood has been observed. The flood arrived at Lijin Stastion on 25th with peak discharge of 10,400 m^3/s. This flood was formed mainly because of heavy rainfall happened in the trunk and tributaries area below Sanmenxia. The peak discharge has the characteristics of high water level, great volume, sharp coming, low sediment concentration and long duration. The discharge greater than 10,000 m^3/s at Huayuankou Station had maintained for 81 hours and the total volume of flood in 7 days was 6.1 billion m^3. The water level along 400km long narrow section, where is mostly located in Shandong Province, had exceeded the guaranteed water level, in which, the water level at Luokou Station had exceeded 1.09m. The time of exceeding guaranteed water level of each place was between 35~80 hours respectively. After natural retarding in Dongping Lake, the water level at some sections in the lake was 0.1m higher than that of the crest of lake dykes, and making the situation very dangerous. Through about million of people and the army men day and night hard working, more than 600km long secondary dykes had been rush repaired and disasters of dyke breaching had been prevented. According to statistics that there were more than 1,290 various danger situations occurring in Shandong section where flood situation was grimmer. But they were out of danger one by one after rush repair. This was a successful case of flood control by relying on dykes because there was no reservoir on the Yellow River at that time.

2.1.4.2 1982 flood

On August 2,1982, a peak discharge of 15,300 m^3/s occurred at Huayuankou Station located on the lower Yellow River, which was the second major flood comparing with 1958 flood since the Yellow River came back to its original course. This flood was also formed by rainstorms happened in the reach from Sanmenxia to Huayuankou. The flood volume of Huayuankou Station in 7 days was 5.002 billion m^3. The floods with discharge greater than 10,000 m^3/s lasted 52 hours and the average sediment concentration was 32.1 kg/m^3. The section from Huayuankou to Sunkou had been silted. Comparing with 1958 flood of 22,300 m^3/s occurred at Huayuankou Station, even discharge along the channel was 6,000~7,000 m^3/s less, but the flood level was about 1m higher at the section from Huayuankou to Sunkou, and, 2.09m higher at Liuyuankou because of aggradation of the channel. In this flood,. Dykes and vulnerable spots of the 887km long Yellow River by the flood were in danger for about 1,079 times. 310,000 army soldiers and people took part in rush repair through emergency mobilization and retarded floods to Dongping Lake. Finally the flood flowed into the sea safely.

2.1.5 Flood Control Benefit on the Lower reach

The economic benefit of flood-control on the Lower reach is calculated upon the overall benefit through operation of the flood-control works on the lower Yellow River, the Sanmenxia Reservoir, and the flood-control works on the Yi, Luo and Qin Rivers as well as the non-engineering flood-control works. For 38 years from 1951-1987, the accumulated static investment has been about 3.987 billion RMB (price in those years) in flood-control. Among which, infrastructure 2.366 billion RMB, institution fee 860 million RMB, operating fee 638 million RMB, and resettlement fee 123 million RMB. The labor input converted is equivalent to 760 million RMB. The flood-control economic benefit amounted to 50.492 billion RMB (those years price), prevented 927,000 hm^2 of cropland from being flood, and, created negative benefit 695 million RMB. The net flood-control benefit will be 45.05 billion RMB if deducting the total investment and negative benefit as well as the labor input converted. The flood-control benefit will be 61.788 billion RMB if calculation upon the unchangeable price in 1980. Up to now, the central government has already invested 7 billion RMB in flood-control, the total benefit of flood-control and hazard reduction may reach to 400 billion RMB if adding the indirect economic benefits.

2.2 Development and Utilization of Water Resources

2.2.1 Current Situation of Water Demand and Supply

The Yellow River is the important water resources on north-west China and North China plain. It will not only be satisfactory to the demand of water usage for the basin region economic and social development but also supply water for the users neighboring its basin and keeping certain quantity of water volume for sediment flushing into the sea.

Based on the calculation of 56 years series statistic data from 1919-1975, the annual mean natural runoff volume of the Yellow River measures 58 billion m^3. Ground water potentiality is about 45.3 billion m^3. The total volume is 72.8 billion m^3 after deducting repetitive calculated volume 30.5 billion m^3 of river runoff and ground water.

According to statistics, the current state of water diversion and usage of the available river runoff reaches to 39.5 billion m^3, and water consumption 30.7 billion m^3. Agricultural irrigation is the main user, with annual diverted water volume 36.2 billion m^3 and consumption 28.4 billion m^3, occupying 92% of the total water consumption. Industry and urban area amounts to 3.3 billion m^3 and with water consumption 2.3 billion m^3, occupying 8% of the total water consumption. Currently, the exploited ground water volume reaches 9.7 billion m^3, among which, 2.3 billion m^3 is on the upper river, 5.4 billion m^3 on the middle river and 2 billion m^3 on the lower river. The water mentioned above mostly concentrate in the major tributaries, like Fenhe river, Shushui River, Weihe River, Wei River and gullies of the river basins etc.

2.2.2 Irrigation State

The total irrigated area in 1949 was about 800,000 hm^2 in the Yellow River Basin and lower reach, and expanded to7.126 million hm^2 in 1990, among which, 5.125 million hm^2 was benefited by the surface water consitituting 72% of the total irrigation.2.001 million hm^2 was benefited by the well irrigation constituting 28% of the total. The Ningxia and Inner-Monglia Yellow River plain irrigated area on the upper reach, the Fen and Wei Rivers basin irrigated area and the irrigated area on the Lower River, the three large-scale segments, are the more concentrated irrigated area by the Yellow River, well developed in cropping and are the important grain and cotton production bases in China, all together totaling 5.658 million hm^2, covering 79% of the total number of the riverwide.

The benefits of the irrigation by the Yellow River are obviouse. According to statistic, unit grain output increasion with irrigation is from 3-5 times rather than that of which without irrigation system. The acculmulated increased grain output from 1950 to 1995 in river-wide amounts to 254.855 billion kg, cotton 2.58 bilion kg, oil-bearing cropping 7.05 billion kg, sugar beetroot 10.254 billion kg. The money value of benefits by irrigation calculates 179.74 billion RMB based on the price of the same year. The current value will be 451.323 billion RMB if refering to the price of 1995. At the same period, the total investment on the irrigation in riverwide is 42 billion RMB, the ratio of investment and benefits is 1:4 with bretty good economic benefits.

2.2.3 Water demand of urban and industry

The water supply work in the Yellow River basin has a long history. There are many built structures in solution the water demand of Beijing, Tianjin and the major cities and townships along the river, however, such supply is not in huge quantity. Since 50's of this century, water

supply works has been rapidly developed. Along with the development of industry and water demand of urban area, the water supply range extends as the time being, covering various cities, counties and townships and, the major industries are also included in huge increasingly demand rate. The water supply covers three kinds, the industry, living and others (the public, green plantation, environment beatifying as well as the environment taking and gardening etc).

In 1990, the industries and urban water uses accounted for 6.48 billion m^3, among which, industrial uses 5.15 billion m^3, taking 79%, the urban uses 1.33 billion m^3, occupying 21% (as shown in Table 2.2.3). The water supply works were normally built up and managed by the city public infrastructure institutions. Quite a big number of the structures works on the ground water except a few numbers works on the surface water. For the large-scale industries, which are the bigger user of water, mostly rely on the river water, have their own water supply works for their own uses.

2.2.4 Hydropower generation

There are nine major multi-purpose projects and hydropower stations constructed on the main stream of the Yellow River as follows: Longyangxia, Liujiaxia, Yanguoxia, Bapanxia, Qingtongxia, Sanchenggong, Daxia, Tianqiao and Sanmenxia etc. and there are Nina, Lijiaxia, Wanjiazha and Xiaolangdi multi-purpose project under construction. The total capacity of 13 reservoirs including accomplishment and under construction, is 56.35 billion m^3 with 35.57 billion m^3 effective storage. And the total installed capacity is 9.156 million KW, and annual average power generation is 34.31 billion kW.h that respectively takes 29.3% of the available exploited hydropower installed capacity and 30.2% of annual hydropower generation on the main stream. The construction of these projects on the main stream does not only exploits water and hydropower resources, but also brings tremendous comprehensive benefits in terms of flood control, ice-run flood control, siltation reduction, irrigation, water supply etc, which plays a important role in promoting national economic development and harnessing the Yellow River.

Table 2.2.3 Industry and urban water uses of eight provinces along the Yellow River in1990.

province	Total						industry		urban	
	Water uses			Water consumption			Water use	Water consumption	Water use	Water consumption
	Sub-total	Percentage(%)	Ground water	Sub-total	percentage	Ground water				
Qinghai	3.50	5.4	2.37	2.65	5.9	1.80	3.11	2.34	0.39	0.31
Gansu	11.18	17.3	6.63	7.26	16.2	4.30	9.81	6.37	1.37	0.89
Ningxia	5.28	8.1	4.23	3.56	7.9	3.02	4.52	3.04	0.76	0.52
InnerMongolia	4.94	7.6	3.16	4.79	10.7	3.12	4.14	4.02	0.80	0.77
Shanxi	8.90	13.7	7.68	8.90	19.8	7.68	7.08	7.08	1.82	1.82
Shaanxi	10.24	15.8	8.36	5.14	11.5	4.18	6.60	3.31	3.64	1.83
Henan	13.53	20.9	6.19	5.33	11.9	1.40	11.03	3.89	2.50	1.44
Shandong	7.24	11.2	2.40	7.24	16.1	2.4	5.26	5.26	1.98	1.89
Whole river	64.81	100	41.02	44.87	100	27.90	51.55	35.31	13.26	9.56

2.2.5 Navigation

It has long history for navigation on partial section of the Yellow River. As early as Warring State Period(647BC), it recorded “the grain of Qing State has been transported into Jin State by shipping”. During Han and Tang Dynasties, partial sections of the upper and middle reach were used for navigation. By end of Qing Dynasty and early of the Republic of China, with the construction of highway and railway, the navigation on the Yellow River declined with each passing day. Currently, only short distance and seasonal transportation by shipping for passengers and goods take place on partial section of the main stream with annual transportation 380,000 - 630,000 ton. The present state of navigation on the main stream shows on the table 2.2.5.

Table 2.2.5 Present Status of Navigation on the Main Stream of the Yellow River

Section	Section in between	Distance(km)	Ship size (t)	Navigation Period		No.of passengers (ten thous.)	Quantity of goods (ten thousand
				Month	Days		
Upper reach	Lagan-Longyangxia	109	8			2.5	
	Binglingshi-Lijiaxia	41			150	11	
	Lanzhou municipal area	11			300	10	
	Wuhai-Sanshenggong	109	200	4-10			2-3
	Sanhuhekou-Lamawan	332	300	4-10	183		2
Middle reach	Liangjiaqi-Hequ	17	10				3
	Tianqiao-Hejiapan	335	15-20	4-10			3-5
	Chuanwo-Yumenguan	9	10-15	4-10			2-3
	Tongguan-Sanmenxia	115	100	11-6			1
	Jiaozhi railway bridge-Mengjing	19	10-20		300		0.7
Lower reach	Gaocun-Weishan	173	100-300				4-5
	Weishan-No.1 dam	332	60-500	3-11			20-40

The navigation condition of the Yellow River is very poor, there are many dangerous shoals on the most section of upper, middle and lower reaches with rapid flow, and it is frozen in the winter season. The middle and lower reaches are sediment-laden section with great variation

between aggradation and degradation, it meanders and shifts abruptly, and flow variation between flood period and non-flood period is great, and partial sections are frozen in the winter season. At present, the passenger-cargo transport by shipping on the main stream of the Yellow River become less, especially on the lower reach. Recently, with the growth of water uses in industry and agriculture sectors, which results in cut-off of the lower reach year by year, there is no navigation basically on the lower reach of the Yellow River.

2.2.6 Water pollution and its monitoring and assessment

The major industry cities in the Yellow River Basin are: Lanzhou, Yinchuan, Baotou, Sanmenxia etc on the main stream, Xining, Taiyuan, Xian, Luoyang,Taian etc. on the tributaries. With the growth of population and rapid development of industry and agriculture production, a great deal of industry sewage has been directly drained into the river without treatment which results in worse of water quality.

The Water Resources Protection Bureau of the Yellow River Basin was set up in 1975. A number of works has been done in the water resources protection regarding monitoring of water quality, scientific research, water environment management and planning in the past 20 years. The water quality monitoring work in the Yellow River Basin started in 1972, which was conducted by the Department of Public Health along the Yellow River at that time. The Yellow River Conservancy Commission (YRCC) has formally managed the monitoring work on the intakes of main stream and tributaries since 1978 . and water quality monitoring work for each tributary has been done by each provincial(region) water conservancy bureau and environment protection bureau. By the end of 1994, 340 water quality monitoring stations, 30 analysis labs have been built up on the whole basin to monitor 40 ODD items of water. Through these practices, 1.2 million data on water quality has been acquired and 3,300 odd station year data of water quality and 70 odd station year monitoring data have been issued, water quality database has been established so as to provide basic information of water quality on whole river.

Based on monitoring data, 2.1 billion ton sewage had been drained into the river in the early stage of 1980s. Since 1990s, sewage drained into the river has sharply increased up to 4.17 billion ton. At present, there are 300 major pollutant sources on the main stream. According to analysis on the 1997 water quality monitoring data, the river length with which water quality can meet drinkable water standard of category II and III only takes 17% of the total assessing river length. The severe water quality pollution aggravates the shortage of water resources in certain extent. The shortage of water resources and worse of water quality has become unfavorable condition to restrict economic development of the Yellow River Basin., and lead to water environment issue on the Yellow River Basin.

Based on “Water Pollution Protection Law” issued by the China government, the construction of legal system on water resources protection is under going, and some local water resources protection regulations, and standard for drained pollutants has been formulated, and “Water Resources Protection Act on the Yellow River Basin” is under modification. And each province along the Yellow River has adopted effective measures to control water pollution, taking

establish sewage treatment system combining a number of scaled treatment in city and township with internal treatment of enterprises.

2.2.7 Anti-drought and hazard reduction

Facing successive occurrence of drought on the Yellow River basin, various level local governments have adopted a series of drought-fighting and prevention measures, such as constructing water conservancy projects, developing irrigation, conducting soil conservation, constructing capital farmland, water-saving projects. And another measures also adopted, for example, establishing drought-fighting squad, extending prevention technology of rain fed agriculture, applying chemical mehod for drough-fighting and hazard reduction etc. In order to alleviate the situation of dry river and solve water demand for drought-fighting of major cities beyond the river basin, water has been transferred from upper reservoirs to lower reservoirs, from inside river basin to outside which plays an significant role in development of local economy.

By the end of 1996, the accumulated investment by the State government was 42 billion Yuan on the following projects: 10077 large, medium and small-sized reservoirs, ponds and dams, 33355 pumping stations, 380000 wells, hundred sluice gates and lift stations. With accomplishment of a number of irrigation projects, which further upgrades guarantee rate of the water supply for the irrigation area between Ningxia and Inner Mongolia Autonomous Region, and irrigation have been basically realized in Guanzhong plain. And irrigated areas in Shandong and Henan have been extended quickly. Irrigation area inside river basin and on the lower reach has increased rapidly which create favorable condition for stable and high yield of crops and increase ability of fighting against drought. Taking Shandong as an example, 70 years drought occurred in 1989, the grain has increased by 1.6 million ton with irrigation and decreased 1.35 million ton without irrigation.

2.2.8❄ Development of water resources and water saving policy

2.2.8.1 Policy of Development of Water Resources utilization

● ❄ Strictly Excuting " A Plan of Distribution of the Available Supply Water of the Yellow River"

In order to well coordinate the water demand of the multi-users in different area and different user within the Yelow River basin and along the Yellow River, with the approval of the State Council on principle, the administrative office of the State Council approved and transmitted the Plan of the Available Supply Water Distribution by Guo Ban Fa (1987) No. 61 Official Document before the operation of the Water Transferring From North to South Project, throughout all the Provinces and autonomous regions, and strongly request carrying out water-saving measures in all cases and formulating individual water usage planning dependent upon the plan of the Available Supply Water Distribution of the Yellow River.

● ❄ Implementing Water Fetch Permits System by Law

Based on the "Water taking Permits Implementation Action" and related regulations, Yellow River Conservancy Commission (YRCC), is responsible for implementing, supervising and managing the Yellow River basin water fetching permits, and fully and partially in charge of the management of the water fetching from the main stream and the major joint-tributaries over the next province, and implementing total water volume usage in control for each province and autonomous regions along the Yellow River.

●❄ Unified Water Management for Main Stream

On Dec. 1998, with approval of the State Council, China State Development and Planning Commission (CSDPC) and Ministry of Water Resources issued and implemented A plan of Annual Available Water Supply Distribution and Water Volume Regulation of the Main Stream of the Yellow River and Terms of Water Volume Regulation & Management by "Ji Di Qu (1998) No 2520 Document". Such Plan and Terms stipulates that the unified management and regulation for water of the Yellow River is on the responsibility of the YRCC and formulates the regulation principle, limits of authority, usage application and examination and approval, and the water usage monitoring and supervising as well as the rule of readjustment of pre-scheme of regulation of water in real time.

2.2.8.2 Water Saving Policy

● ❄ Increasing Investment on Water Saving Works and Greatly Supporting Farming Water Saving Projects.

Farming water saving irrigation practices is the key issue in terms of implementing the water saving all over the Yellow River basin. Condition 26 of Chapter 4 of the "Policy of Water Resources Industry" of the State Council stipulates: various government project approval authorities should select and list the farming water saving project on priority with additional investment. As for water saving project, which is matchable to the conditions of loan and has capability of repayment, National Development Bank and Agricultural Bank should firstly arrange loan. Various level people's government should arrange financial sources as interest deduction for the farming water saving project according to different condition. The "Policy of Water Resources Industry" of the State Council defines the guidelines and directives of vigorously supporting the farming water saving irrigation project in all ways.

●❄ Raising Water Price

For a long time, due to water price too lower resulting in flooding irrigation is the major reason of water wasting in usage. The condition 20 of Chapter 3 of the "Policy of Water Resources Industry" of the State Council defines that the water price supplied by the original water supply works should be made be operational and in place within 3 years gradually (during the "Ninth-five Year Plan) referring to the state water price policy and cost compensation, the principle of rational benefit charge and different usage purpose, and timely readjustment of the

charges by changes of water supply cost. At present, the rational water price at the head of the canal on the lower Yellow River has been submitted to the SDPC for approval.

●❄ Raising Charge for Excessive Quota of Water Usage

Implementing different water price charge and adopting progressive rate for excessive quota of water usage is one of the effective measures of dealing with water saving domestically and overseas. The Condition 27 of Chapter 3 of the "Policy of Water Resources Industry" of the State Council clearly defines: Extra fee should be added up in case of water usage excessive the quota.

● ❄ Management Reinforcing, Water Saving as the Strict Condition in Examination and Approval of Project Listing

Management Reinforcing is one of important practices in effectively water saving. It is the only way to eliminate the water uses wasting cases at the beginning in strict examination and approval project implementation. YRCC and the water administrative authorities in each province and autonomous regions should exams and approve the proposed water diversion project in conformity of the regulation systems of water uses saving. Responsible Planning Department should refer to the stipulation of "A separate demonstration of wording of water saving uses should be included in the proposal of project with high water consumption, otherwise, it can not be listed and implemented in case that against it" as Condition 27 of Chapter 4 of "Policy of Water Resources Industry" to exam and approve project.

●❄Study Emphasizing and Extension of Water Saving Technology

Central State Government strongly stresses the study and extension of water saving technology, Water Law of the People' Republic of China stipulates and authorities various level people' government to encourage and reward model workers and institutions who have achieved greatly results in water saving technology study. "Policy of Water Resources Industry" of the State Council also regulates much effort should be stressed on water saving and study and techniques extension.

2.3 Soil Erosion and Water Conservation

2.3.1 Soil and Water Loss on the Loess Plateau

The Loess Plateau is most severe soil eroded area not only in China, but also in the World with total eroded area 454,000 km^2, among which, water eroded area covers 337,000 km^2, and wind eroded area covers 117,000 km^2.

By analysis, the area with erosion modulus greater than 5000t/ km^2.a is 146,500 km^2, which takes 38.9% of the total same category of China. The severe water eroded area with erosion modulus greater than 15000t/ km^2.a are about 36,700 km^2, which takes 89% of the total in China. The long –term average sediment inflow to the Yellow River is 1.6 billion tons with sediment concentration up to 35kg/ m^3, which is 29 times of that on the Yangtze River.

The Sediment of the Yellow River is mainly from sediment-laden and coarse- sediment area on the Loess Plateau. The total area is about 212,200 km^2, among which, area with annual erosion

modulus greater than 5,000t/ km^2.a are 191,000 km^2 (including wind eroded area). And average annual sediment inflow to the river from this area is 1.4 billion tons, taking above 80% of the total of sediment transport, among which, coarse sediment (Particle size D>0.05mm) takes 50%-70%.

Above 80% sediment of the total on the middle reach of the Yellow River concentratedly produces during flood period from June to September.

Artificial impact on soil and water losses show as follows, the first, cultivating steep slope and destroying forest, grass and natural vegetative cover. Secondly, destruction of vegetative cover, landscape and soil caused by mining, road construction and house construction. Based on investigation, statistics and analysis of related units, new increased soil and water losses caused human being take above 10% of the total, it will reach up to 20% within area with intensity of human being activities since founding of the People's Republic of China.

Soil erosion of the basin has coursed losses of topsoil together with water, soil and fertility. There are 40 million ton fertilizer including nitrogen, phosphate and potassium that will be lose together with 1.6 billion tons of sediment which is the annual delivery in the Yellow River for many years. The severe soil and water loss has not only worsen the deposition of the channel in the lower reaches and increased the threatening of flood control of the lower reaches, but also worsen the drought of the local area. Soil and water loss has severely restricted the local economic development.

2.3.2 Soil and Water Conservation

By end of 1997, accumulated accomplished preliminary treatment area of 7 provinces on the loess plateau was 166,000 km^2, taking one third of soil and water loss area. It built 5.53 million hm^2 of capital farmland; planted 8 million hm^2 of soil conservation trees and 2.33 million hm^2 grasses; built 100,000 warping dams and more than 980 key dams. The grain output has been increased more than 4 billion kg annually, solved 10 million people and 15 million domestic animals' drinking problem.

Through the soil and water conservation measures, the sediment flowed into the Yellow River of the basin has been reduced 300 million tons, making up 18% of 1.6 billion tons of average sediment delivery for many years.

2.4 Promotion of the river harnessing with advanced technology

The mass of scientific and technical staff members have accumulated a completed systematic basic data and conducted detailed studies on the Yellow River which is a complicated and difficult to be managed river in the world through closely combining their practice. They have achieved a large number of achievements that has reached world advanced level on the aspects of basic pattern of sediment movement of Yellow River floods, management, development and planning of the Yellow River, irrigation and hydro-electric projects construction, various river engineering works construction, soil conservation works construction and the development and utilization of

water resources, bringing a great advance in continuous progress of science and technology on the river management and development of the Yellow River.

3. Problems in the river harnessing

3.1 The flood threat in the lower reaches

3.1.1 Difficulties in "suspended river" control

The floods of the lower Yellow River mainly come from three regions of Hekouzhen-Longmen, Longmen-Sanmenxia and Sanmenxia-Huayuankou. The rainstorms of these three regions are frequent with high intensity and short duration. The formed floods have the characteristics of high peaks, suddenly rising and suddenly falling. Especially the floods formed above Sanmenxia, have very high sediment concentration and caused serious sedimentation on the lower reaches. There always have been the main disaster floods to the lower reaches.

During the period of 1950—1998, about 9 billion tons of sediment deposited on the lower channel of the river in all, causing the water level higher than that of the same discharge. Especially in the last 10 years, the main channel has been seriously deposited, discharge capability decreased and bankfull discharge has been reduced from 5,000—6,000 m^3/s in 1980s to 2000—3000 m^3/s at present. In 1996 flood season, Huayuankou station occurred 7600 m^3/s dominant flood, its water level was 0.91 m higher than that of 22,300 m^3/s flood occurred in 1958; all the floodplains along the river had been inundated and the high floodplains in Yuanyang and Fengqiu where had not been inundated for 141 years since 1855, almost all had been flooded. The continuous deposition of the riverbed has caused more opportunities of over flooding, river channel wide, shallow and disordered, the unfavorable conditions of a secondary elevated river becoming worse and worse and increasing the danger of flooding.

3.1.2 Uncontrolled floods in the range from Xiaolangdi to Huayuankou

After completing the Xiaolangdi Reservoir, it will play great functions on flood control and sediment reduction of the down stream of the Yellow River, the flood control standard of the channel at the down stream can be increased to meet a flood once in a thousand years and keep no remarkable deposition for about 20 years in the lower channel of the river. The disasters caused by the dyke breaks are still existed because the maximum flood with peak discharge at Huanyuankou Station since 1949 would be possibly happened in the lower reaches of the Yellow River. At present the standards of dykes and the other engineering works at down stream could not reach to the protection standard in the year 2000, so it is necessarily to speed up the construction. After Xiaolangdi Reservoir putting into operation, a flood with discharges from 13,000 m^3/s (a hundred year frequency) to 20,000 m^3/s (a thousand year frequency) still will be possibly happened in the reach between Xiaolangdi to Huayuankou, where the flood can not be controlled by the Xiaolangdi Reservoir. At same time, the amount of water and sediment flowing into the down stream will be changed greatly and the scouring and deposition and the river pattern as well of the

lower river also would be regulated correspondingly. Especially at the early stage of reservoir operation, the silt concentration of outflow is less; the river bed in the lower reaches will be cutting down and the flood plain collapse; the part of river engineering works would be scoured severely: the wandering situation of the river pattern can not be changed quickly and; the benefits of sediment reduction of the channel below Aishan is not remarkable. The river pattern will be changed again, the problems of the dykes strengthening and height and few river training works are still existed and the dangers of dyke breaks caused by floods still might be happened.

3.1.3❄ Difficulties in water and sediment regulation

The average amount of runoff for many years of the Yellow River basin is 58 billion m^3 and the average sediment transport for many years is 1.6 billion tons. In order to control the speed of deposition in the lower reaches, it should be operated the Sanmenxia and Xiaolangdi Reservoir to regulate water and sediment and the average discharging capacity for years should not be less than 20 billion m^3 at Lijin Station, among which, 15 billion m^3should be kept in flood season. According to statistical data of 1990s that the average volume of water flowing into the sea has less than 20 billion m^3 and only 1.9 billion m^3 in 1997. According to the forecasting, the present water shortage of Yellow River water supplied area is 2.67 billion m^3, 6.9 billion m^3 short in 2010 and 15 billion m^3 short in year of 2030. It will be no water to transport sediment before realizing the project of water transfer from south to north. In that case it will be very difficult to control the deposition of the channel in the lower reaches and it will threaten the flood control of the lower Yellow River.

3.2❄ Conflicting in water demand and water supply

3.2.1 Contradiction in water supply and water demand

The Yellow River, flows through the arid and semi-arid areas in the north-west regions and the regions of northern China, is the main water source in this region. According to the development of national economy, the water requirements in inside and outside of the river basin are increased rapidly and the contradictions of supply and demand are projecting day by day. It mainly shows on the following aspects: firstly the capability of water supply beyond the river channel can not meet the demands of domestic use and industrial and agricultural use, and parts of regions are short of water seriously; secondly the contradictions of the water use beyond the river channel and the water uses among sediment transportation, ice run control, environment, power generation and others are projecting; thirdly the contradictions of water supply between regions are sharpening.

3.2.2 Frequent river dry-up in lower reaches

Frequent depletion at down stream of the Yellow River began from 1972, for 27 years from 1972 to 1998, Lijing Station had no water for 21 years, which amounted to 1050 days; among

them, in the 9 years of 1990s, there were continuously no water for 8 years, which amounted to 859 days, making up 82% of that of no water in 27 years. The most serious no water was in 1997, Lijing station had 13 times no water, which amounted to 226 days, among them the river-cut off in one day was extended from there to the nearby Heigangkou of Kaifeng, in Henan Province, the river section length of no water was up to 704 km and was 90% of the total length of the river course on the lower Yellow River. Since 1990, the times of no water in the lower Yellow River have been increased greatly and the time of no water has been prolonged; the months of no water have been increased and the river section length of no water is extended; the first time of no water has been advanced and the no water days during the main flood season have been prolonged; the more near the river mouth, the more serious the degree of no water (see Table 3.2.2). No water in the lower Yellow River is caused by many reasons, to sum up, the water resources of Yellow River can hardly meet daily increased demands of social economy and the development requirements of ecological environment. Concretely speaking:

Table 3.2.2 Statistic table of depletion at Lijin Station over the years of the lower Yellow River

Year	**Earliest date of depletion** (day & month)	Number of days in July & Sept.	Times of depletion	Number of days depletion in a year			Distance of depletion (km)
				Whole day	Intermittence	Total	
1972	4.23	0	3	15	4	19	310
1974	5.14	11	2	18	2	20	316
1975	5.31	0	2	11	2	13	278
1976	5.18	0	1	6	2	8	166
1978	6.3	0	4	0	5	5	104
1979	5.27	9	2	19	2	21	278
1980	5.14	1	3	4	4	8	104
1981	5.17	0	5	26	10	36	662
1982	6.8	0	1	8	2	10	278
1983	6.26	0	1	3	2	5	104
1987	10.1	0	2	14	3	17	216
1988	6.27	1	2	3	2	5	150
1989	4.4	14	3	19	5	24	277
1991	5.15	0	2	13	3	16	131
1992	3.16	27	5	73	10	83	303
1993	2.13	0	5	49	11	60	278
1994	4.3	1	4	66	8	74	380
1995	3.4	23	3	117	5	122	683
1996	2.14	15	6	122	14	136	579
1997	2.7	76	13	202	24	226	704
1998	1.1	19	16	114	28	142	449

Firstly the water resources of Yellow River are short. The per capita water consumption is only 25% of whole country, the per capita water consumption, for per mu farmland, is only17% of the whole country which belongs the water shortage of resources. Because the precipitation in 1990 was less and Yellow River came into the dry season, the measured runoff was reduced greatly. Since 1990, the measured runoff of average annual in Huayuankou Station is 26.8 billion m^3, which reduces 21.5 billion m^3 than 1950; the measured runoff of average annual in Lijing

Secondly the water consumption is increased speedily. On an average, the runoff consumption of Yellow River in 1950 was 12.2 billion m^3 a year. On an average, the runoff consumption of Yellow River since 1990 exceeds 30 billion m^3 a year. Yellow River is also a sediment-laden river. With the demand of flood protection, under the current conditions, the mean annual water demand of river course on the lower Yellow Rive for transporting the silt into the sea can be no less than 20 billion m^3. Owing to the water consumed by others in the river course, the water supply capability of Yellow River is limited. Facing the day by day increased water supply demands, the water of Yellow River is really to hardly meet the above-mentioned demands.

Thirdly, the water consumption phenomena are seriously. Agriculture is the big water user of Yellow River, the utilization rates of water resources are only between 30 % to 50% of the total and the water consumption phenomena are seriously due to the weak management, old and aging works, weak corollary equipment and higher water consumption quota in most irrigation regions. The re-water utilization rates of industry are only about 40% of it and the water consumption phenomena also are existed.

Fourthly the water price is very low, which even much lowers than the costs of water supply. At present, the water price of water/m^3 in the head of cannel diverted from Yellow River on lower Yellow River is between 0.0048 to 0.0065 yuan, which was a half of the cost; in some irrigation regions by gravity of Yellow River basin, the water price/m^3 is about 0.0173 yuan and insufficiently is 1/3 of the costs. Owing to the lowest water price and short of water saving consciousness by people, the economic level can not play the functions for adjusting and controlling the water volume diverted from Yellow River.

Fifthly, the unified management and water dispatching system of water resources in whole Yellow River has not been built up. In some places, the works with higher water consumption are still being built without considering about the conditions of the water source. The inadequate water resources are aggravated, it is hardly to make overall planning by taking all factors into consideration on the upper, middle and lower reaches of whole Yellow River and distributes the water rationally because of fighting for water in various places during the peak of water consumption.

Sixthly, the capabilities on regulating and storing of the reservoirs on the main tributaries of middle Yellow River are seriously insufficiently. At present, only Sanmenxia Reservoir on the middle Yellow River can regulate limitedly, it, combined with the ice flood dispatching, only can store about 1.4billion m^3 water at most during February and March of general year, which is far away to meet the water demands of down stream of Yellow River because of silted reservoir area and limited elevation of Tongguan.

The frequent depletion of the Yellow River has worsen the deposition of the main channel, reduced the capacity channel sluicing, caused losses of industrial and agricultural production, made drinking water difficult for urban and rural residents, destroyed biological balance and worsen the biological environment of delta area and water quality.

3.2.3 Serious water pollution

The water of the Yellow River has been polluted day by day. According to the forecasting that along with the basin economic development, the wasted water discharge of the whole basin will reach 5 billion tons in 2000, 2.3 times of that discharging in 1980s and it will be 6.5 billion tons in 2010, 3 times of that of 1980s. The severely water quality pollution has increased the shortage of water resources.

3.3❄ Heavy task in soil and water loss control

3.3.1❄ Difficult in harnessing the water and soil loss

The life of the local people in the loess plateau is very poor and difficult. They need a great support from the state to speed up the management. In recent years, although the state has increased the investments in this area, the controlled area is only 6000 km^2 annually due to the adverse circumstances and people destroyed the condition while doing the management. The uncontrolled area will be more difficult to manage. Thus, the difficult of management is great.

3.3.2❄ Accelerated soil erosion with human activities

The water and soil conservation facilities are often damaged due to opening up wastelands, damaging forest and grass, building roads for exploiting mines and production construction without paying much attention on the water and soil conservation. Especially in the " Black Delta '' area (means coal mine area) bounded by Shanxi, Shaanxi and Nei Monggol and the " Gold Delta " area (means gold mine area) bounded by Henan, Shaanxi and Shanxi, the water and soil erosion phenomenon caused by the people are seriously. In the " Black Delta " area with 54,000 km^2, there are more than 1,000 various coal mines, the spoil volumes were up to 0.12 billion tons in 1986 and 1993, the erosion modules of soil in this region increased 6 to 9 times than before and it is estimated that 60 million tons sediment discharged into Yellow River will be increased yearly in 2010 if the controlling progress is not speeded up. In the " Gold Delta" area, 482km^2 plant cover areas are damaged by exploiting mines, the total spoil volumes are up to 38 million tons and 137 water conservancy and water conservation facilities are damaged. According to findings statistics, the water erosion areas since more than 40 years have been increased to 50000 km^2, more than 7.89 million mu natural forest areas on Ziwuling and Liupanshan Mountains have been reduced and occupy 24% of original forest areas. The forest border line has been drawn back to 10-20 km for average.

3.3.3❄ Insufficient investment

In fact the controlled area of water and soil loss has not really controlled the water and soil loss due to uncompleted measures. Its annual erosion modulus still has exceeded 1000 t/km^2 which only can be considered as preliminary control. From actual demand point of view that if the

local regions reach the standard, it will require 500,000 Yuan investment for managing 1 km^2 area through comprehensive measures. At present, the state actual investment is only 30,000 ~ 50,000 Yuan/km^2. Due to less investment and uncompleted engineering works, it has resulted in lower preserved rate of controlled soil and water loss area and it is also difficult to bring about the benefits.

4. Prospect and current corresponding measures

4.1 Flood disaster protection

It will further improve the engineering system and non-engineering measures of flood control on the lower Yellow River in the near future (year 2010) and to prevent the maximum flood happened since the funding of new China in the lower Yellow River, that is: the standard of flood discharge at Huayuankou Station is 22,000 m^3/s. The construction of flood prevention in detention basins will be well conducted and the safety of the people's life and property can been guaranteed. In the long-term plan, it will set up a water and sediment regulation system of the Yellow River step by step, consider the management of hyper-sediment laden and coarse sand areas, effectively control floods and sediment of the Yellow River, make slightly aggradation of the channel in the lower Yellow River for about 100 years and realize the objective of long time safety of the Yellow River.

In order to realize the above-mentioned aims, the policy on " Retaining the Flood in the Upper Stream and Discharging at Downstream and Retarding Floods in detention basins on the Both Banks " should be continuously carried out. The sediment treatment should adopt an overall policy of " retaining, discharging, warping, regulating and dredging " together. The two policies should be combined organically to form an engineering system of flood control and sediment reduction gradually and realize the purpose of long time safe of the Yellow River.

4.2 Alleviation of dry river and contradiction of water demand and supply

To adopt the various effective measures to mitigate the supply and demand contradictions of water resources and river-cut off of Yellow River in the near future (Year 2010); to realize the rational disposition of water resources step by step on the basis of water-saving according to the water distribution plan made by the State Council; the river sections of water source, concentrically supplied the water for the bigger and middle cities on the main rivers and tributaries, can reach the water quality standard with above Type _ and to remove the river sections which are worse than the water quality with Type _. Further mitigating the supply and demand contradictions of Yellow River water resources, the water resources can be optimistically disposed and used continually, forming the water-saving society preliminarily and well protecting the water resources according to the principles on opening up the water sources and saving the water and managing scientifically in the far future (year 2030).

For these reasons, the department responsible for the work of the State Council, the organs of

river basin, some relative scientific research units and all the provinces and regions along the Yellow River strengthen the planning research, make the water dispatching plan in advance and the management methods, work out the distribution plan of down stream and implement the long distance water-transfer according to the situation of day by day projected water supply and demand contradictions of the Yellow River and the dry river condition. Such as: establishing a unified management system of water resources; rationally deciding the water price of water supply; increasing the investment degree, paying much attention on the scientific and technical progress and well doing the water-saving conscientiously; perfecting the laws and regulations system of water resources protection, strengthening the pollution protection and control degrees; strengthening the propaganda education work of water resources protection; building the key works on the main streams of middle reach, increasing the dispatching and storing capabilities of water resources and etc. These measures, in fixed degree, mitigate the supply and demand contradictions of Yellow River water resources and the affections caused by the river-cut off on the lower reach. It still needs to adopt many ways of law, administration, economy and technology and comprehensive control for further mitigating and solving these problems step by step. The general principle is that the water source-opening up and the water-saving shall lay equal stress on and the water-saving shall be taken as the key, and the scientific management and protection of water resources will be strengthened.

Considering the population increase, industrial and agricultural development levels in year 2030 and under the premise of further adopting the measure of water-saving, it predicates that the Yellow River can supply 66 billion m^3 of water, use river runoff 52 billion m^3 and the water shortage is about 15 billion m^3. It is very clear that, Yellow River is short of water of resources. From a long-term view, the water resources of Yellow River for its self are hardly to meet the demands without the water transfer from outside areas. Therefore, this is the strategic measure by thoroughly dealing with the contradictions of supply and demand of Yellow River water resources and the problem of depletion in the lower Yellow River by speeding the steps of early days' work on West-Route Project of water transfer from south to north, trying to start the construction in about year 2010 and realizing the aim of replenishing the water to the Yellow River as soon as possible. The projects of middle route and east route of water transfer from south to north also should consider the problems on supplying the water to part of irrigation regions diverted the water from Yellow River on the lower Yellow River in order to mitigate the water supply pressures of the lower Yellow River by supplying the water to the outside of Yellow River basin.

4.3 Water and soil loss prevention

The aims of controlling in the near future (2010): newly increasing 157,300 km^2 preliminary controlled areas of water and soil erosion, firmly controlling the new water and soil erosion caused by the people, trying to contain the deserting development, winning the initial success by controlling the ecological environment and reducing about 0.6 billion tons sediment flowed into

Yellow River. The aims up to 2030: newly increasing 242,000 km^2 controlled areas of water and soil erosion, clearly improving the ecological environment, winning the success by controlling the water and soil erosion regions and the ecological environments in the key-point controlling regions start to step on the sound track. The aim up to 2050: getting the water and soil erosion regions, suitably controlling, harnessed basically, basically making the slope farmland at 25 into terracing, the ecological environment can be improved greatly and basically making the most regions into green land.

The adopted countermeasures are: according to the water and soil erosion features of loess plateau, dividing the water and soil conservation areas into three regions with Grade 1 and nine regions with Grade 2, that is; the serious erosion areas (including two regions with Grade 2 of gullied loess plateau and gullied rolling loess region), the light erosion areas (including two regions with Grade 2 of loess terraces and alluvial plain), part of erosion regions (including five regions with Grade 2 of forests, earth and rock mountains, highland prairie, arid grassland and dune area). The land utilization direction to the serious erosion regions is that the agriculture, forest and animal husbandry should be developed simultaneously, the per capital farmland is about 2 to 3 mu, 0.5 to 1 mu orchard and economic forest and plant trees and grass in the other lands according to the local conditions. The controlled measures are: " Protecting the Plateau and Strengthening the Gully, Taking the Gully to Conserving the Plateau ", to do the constructions of terrace, afforestation and grass-planting and warping dam, especially strengthen the constructions of key work of controlling the gully. The land utilization to the light erosion areas should take the agriculture as the key, combining the water construction with agricultural development, comprehensively harnessing the mountain, water, farmland, forest and road. The land utilization to the parts of erosion areas shall take the forest and animal husbandry as the key, protecting the existed plant covers of forest and grass and avoiding the causing of new water and soil erosion ; actively adopting the measures of comprehensive control to the parts of damaged lands with forest and grass-planting.